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NOTES ON THE GEOLOGY OF MOUNT KEARSARGE, NEW HAMPSHIRE.

MOUNT KEARSARGE[1] or Pequawket is a mountain of medium height in the southern part of the White mountains of New Hampshire. It is situated a few miles north of North Conway, partly in the town of Bartlett and partly in the town of Chatham. It rises 3,260 feet above the sea, and 2,700[2] feet above the neighboring valley of the Saco river; and includes, as a spur on its southwestern slope, Mount Bartlett. The latter rises 2,630 feet above the sea. These two mountains cannot be separated in a geological study of this mountain mass.

The rock making up the base of these mountains is what Hitchcock has called the Conway granite. On the south slope of Kearsarge this granite is found up to the level of 1,300 feet; on the southwest and west slopes of Bartlett, up to 1,000 or 1,100 feet; on the northwest slope of Kearsarge, up to 1,800 feet; and on the northeast slope of Kearsarge, up to the 2,500 foot level.[3] This granite also makes up the base of Moat mountain, on the opposite side of the Saco river, and is found on the north slope of this mountain in the course of Cedar brook up to the 900 foot level. It is found, in addition, over a broad area around, and is quarried in a number of places. The large quarry in the side of the mountain at Redstone, three miles southeast of North Conway, is in this granite.

The Conway granite[4] is reddish in color, is coarse in crystalline texture, is without foliation or granulation, and is very massive, being cut by few joints either vertically or horizontally. In the quarry at Redstone the distance between the joints is very noticeable. The first joint from the surface, when I was there, was three feet down; the second, four or five feet below the first; and the third, twenty-five feet or more below the second. In working the rock it is necessary to cut the rock horizontally as well as vertically. The size of the blocks that may be taken out is limited only by the strength of the derricks. The few joints seen were parallel with the side of the mountain, indicating, as the mountain has been produced by erosion, that these joints are due to causes acting since the formation of the mountain.

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[1] Geological section of this mountain is represented on the second sheet of the geological map of New Hampshire in the atlas accompanying *Geology of New Hampshire.*

[2] Taken from the topographic map of the *U. S. Geol. Surv.*

[3] Determined by means of an aneroid.

[4] Described in *Geology of New Hampshire,* Vol. II, p. 142.

The orthoclase of the Conway granite is of a reddish tint, and is so abundant as to give its color to the rock. This feldspar occurs in coarse particles an inch or so through, which frequently show Carlsbad twinning. These particles do not present the definite outline of crystals, and do not give a porphyritic appearance. In addition, there is a white feldspar much less abundant, and distributed irregularly, and also in irregularly shaped cleavage particles much smaller than those of the orthoclase. This is a triclinic feldspar, and is twinned according to the albite law.

The quartz is generally distributed in irregular granular masses varying in size from one-half inch to one inch through. It is of a decided smoky-gray color, and, in contrast with the red feldspar, gives a mottled appearance to the rock surface. The quartz masses frequently inclose grains of both the red and white feldspar. There is also quartz distributed in finer particles inclosed in the orthoclase, and entirely separated from the coarser granular masses. These second quartz particles are generally anhedra, but somewhat frequently show distinctly the angles and faces of crystals. This clearly indicates that not all of the quartz crystallized last in this granite, but that a part crystallized before, or along with, the feldspar.

The biotite of the granite is small in quantity, of full black color, and occurs in small, foliated particles rarely more than one-sixteenth of an inch in length or width. It is generally distributed with the coarser granular quartz masses, though some finer scales are inclosed in the feldspar.

In addition the rocks contain a little magnetite.

The specific gravity of the granite is 2.624, and its composition is shown in the following analysis:[1]

SiO_2	73.01
Al_2O_3	13.73
Fe_2O_3	0.44
FeO	1.48
MnO	0.09
CaO	0.94
MgO	0.01
K_2O	5.62
Na_2O	3.50
Loss at 110°C	.05
Loss over blast	.18
	99.05

The weathering of this granite is very characteristic. Every bowlder in the fields has partly or entirely crumbled to a barren ring of gravelly débris. This débris consists of loose, angular, rusty particles varying in size from those an inch through down to fine powder. The particles consist, as far as can be seen, of orthoclase and quartz. The former, during the disintegration, loses its luster and bright flesh-red color, and assumes a dirty rusty color; it does not, however, become covered with a fine powdery coating of kaolin, but is divided into little cleavage blocks by many cracks along the cleavage planes. The angular quartz grains are thrown out by the breaking of the feldspar, and the anhedra and quartz crystals may be found among the particles of the crumbling rock.

The mica is generally decayed, and has changed from a black to a brownish, bronzy, or brassy color. Secondary epidote is frequently seen with the decaying biotite. The triclinic feldspar is rarely seen in the disintegrated particles of this granite.

The analysis of a fair sample of some of the coarser of these particles afforded:

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[1] Other determinations were not made. The methods given in Bulletins 148 and 176, *U. S. Geol. Surv.*, were closely followed.

SiO_2	70.18
Al_2O_3	15.13
Fe_2O_3	00.68
FeO	1.54
MnO	0.13
CaO	0.84
Na_2O	2.67
K_2O	8.93
Loss at 110°C.	0.10
Loss over blast	0.22
	100.42

The disintegration of the rock is both chemical and mechanical. The triclinic feldspar and the mica are the first minerals to decay. The frost and mechanical agents then act between the minerals and along the planes of cleavage in the orthoclase, prying apart the minerals and crumbling the rock. The coarseness of the texture probably materially aids these agents in their work. The comparatively rapid disintegration of this granite does not specially recommend it as a building stone, though the somewhat numerous quarries in it indicate a considerable use of it for that purpose.

Within the Conway granite are found inclusions of an earlier granite. The rock of these inclusions is of a light gray color, of a medium-fine, granular texture, and is perfectly massive, without banding, foliation, or parallel arrangement of the minerals. The feldspar is white and glassy, and is partly triclinic. The quartz is finely granular and slightly smoky, and forms with the feldspar an intimate mixture. The black biotite is so abundant as to give a gray color to the whole rock.

Generally, on the different sides of Kearsarge, as well as on the sides of Bartlett, there is found above the Conway granite a granite-porphyry. In this the feldspar phenocrysts measure about one-fourth inch through. These feldspars are orthoclase, and are in part reddish throughout, and in part reddish on the borders with a white center. The outline of the phenocrysts is generally rounded rather than angular. The quartz, of a smoky color, occurs in part in distinct particles, one-sixteenth to one-eighth inch through, sometimes showing crystal forms. The groundmass of the granite-porphyry consists of a fine granular mixture of reddish feldspar, smoky quartz, and black mica, together with, in some places, fine black hornblende and a little magnetite. Iron pyrites is occasionally seen.

The granite-porphyry does not weather and crumble so rapidly as does the Conway granite; neither does it form any such gravelly débris. It is but a few feet, fifty or so, in thickness on the south side of Kearsarge, and on some sides of the mountain was not observed at all, either because entirely absent or because covered. There is a like granite-porphyry in the bed of Cedar brook on the north side of Moat mountain, where there is exposed an excellent section.

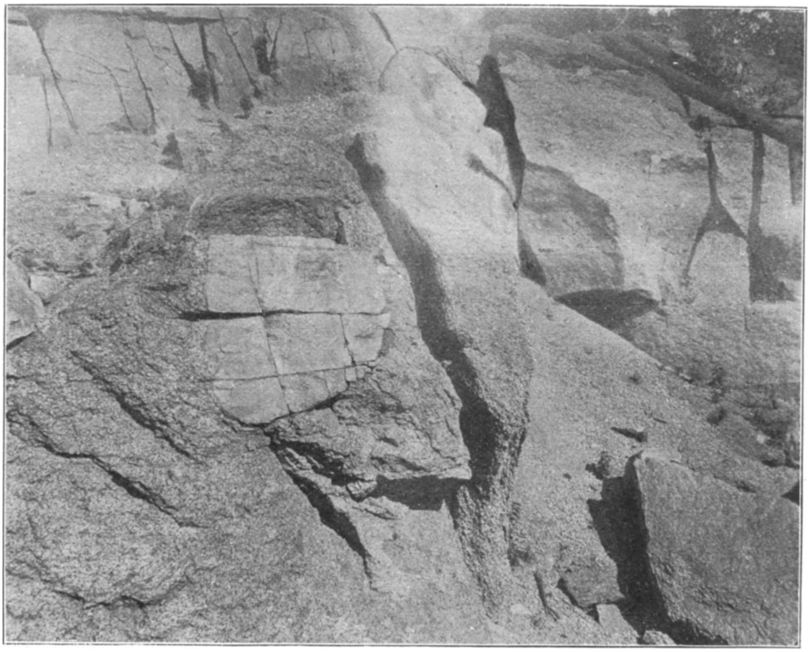

FIG. 1.—Just left of the center of the picture is shown an inclusion of finely-grained gray granite in the coarse Conway granite. Inclusion 3–4 feet in diameter.

Above this granite-porphyry in Mount Kearsarge, or above the Conway granite where the porphyry does not occur, the rock is a quartz-porphyry. This latter rock varies in color from a red to a dark gray. The gray is the prevailing color, while red is more characteristic of the porphyry nearer the granite. The porphyry is massive and without foliation, and is cut by many joints into quite small, irregular, sharply angular blocks.

The quartz is very noticeable. It is smoky in hue, and occurs generally in distinct rounded anhedra one-sixteenth to one-eighth inch through. Now and then among these anhedra may be found a bipyramidal quartz crystal. On the east slope of the mountain, at about the 2,000 foot level, was found a gray quartz-porphyry abounding in quartz crystals, so that every broken surface and every weathered surface presented many of the little projecting pyramids, and the six-sided tapering cavities from which crystals had been broken. The porphyry abounding in quartz crystals is at a considerable distance from the granite beneath.

In the porphyritic phases having the finer-grained groundmass there are orthoclase phenocrysts, but in the coarser-grained varieties the intercrystallizing feldspars constitute the groundmass about the quartz particles with only a trace of the finely grained mixture.

Different specimens of the porphyry afforded on analysis the following results:[1]

	I.	II.
SiO_2 - - - - -	78.37	75.38
Al_2O_3 - - - - -	10.85	11.85
Fe_2O_3 - - - - -	1.33	1.78
FeO - - - - -	0.44	0.88
MnO - - - - -	0.06	0.10
CaO - - - - -	0.40	0.33
MgO - - - - -	0.00	0.00
Na_2O - - - - -	2.68	3.68
K_2O - - - - -	5.52	5.37
Loss at 110°C. - -	0.04	0.15
Loss at red heat - -	0.59	0.50
	100.28	100.02

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[1] Other determinations were not made. Methods given in Bulletins 148 and 176, *U. S. Geol. Surv.*, were carefully followed.

	III.	IV.
SiO_2	72.25	73.33
Al_2O_3	13.40	12.95
Fe_2O_3	1.10	0.98
FeO	1.53	1.66
MnO	0.11	0.13
CaO	0.74	0.98
MgO	0.00	0.00
Na_2O	4.27	3.46
K_2O	5.56	5.61
Loss at 110°C.	0.10	0.11
Loss at red heat	0.31	0.30
	99.37	99.51

I. Coarse quartz-porphyry, red in color, finely granular groundmass small in quantity and distributed among the coarser red feldspars; from the 1,350 foot elevation near the phyllite, on south slope of Mount Kearsarge. Specific gravity 2.614.

II. Bluish-gray quartz-porphyry, groundmass fine, of bluish-gray color, inclosing anhedra of quartz and phenocrysts of red feldspar. From 1,550 foot elevation, south slope, Mount Kearsarge, near phyllite. Specific gravity 2.62.

III. Dark gray quartz-porphyry; from top of Mount Kearsarge. Specific gravity 2.643.

IV. Dark gray quartz-porphyry, abounding in quartz crystals; from eastern slope at about 2,000 foot elevation. Specific gravity 2.64.

With these analyses of the porphyry, together with that of the Conway granite before us, we may consider the relation of the porphyry to the granite. It has been pointed out that there is generally in Mount Kearsarge and Mount Bartlett between the porphyry and granite a granite-porphyry. The best place to study the relation of these rocks in Mount Kearsarge is on the southern slope in the trail. Though the rock surface is not exposed as much as might be desired, nevertheless it is possible to observe a reasonably well defined gradation from Conway granite into the granite-porphyry, and then from the latter into the quartz-porphyry.

But this gradation may be more clearly and easily seen in the bed of Cedar brook in the lower part of Moat mountain.

Beginning at the 900 foot contour in the brook bed, there appears what is clearly the Conway granite, though possibly a little finer in texture than the granite farther down the stream. Ascending the brook bed a few feet, the rock begins to be slightly porphyritic, and at the same time contains less biotite. There may be distinguished in this phase the beginning of a finer-grained groundmass. Then 150 feet up the brook bed, only 20 feet or so higher vertically, the surface of the ledge being exposed all the way, may be found the granite-porphyry. Its resemblance to the preceding is very close, yet the fine groundmass of a light gray color is clearly defined, inclosing the distinct feldspars, one-half to three-fourths inch through, and the blebs of smoky quartz, together with the black foliated masses, one-eighth inch or less through, of biotite. The biotite is noticeably less in quantity than in the granite beneath.

This gradual variation and gradation may be easily traced until, at the 1,100 foot level, the rock is a quartz-porphyry, the biotite appearing not at all, or now and then only in traces, and the rock, aside from this, identical with the quartz-porphyry higher in the mountain.

The quartz-porphyry of these mountains has thus far been spoken of as if it were a simple and pure porphyry. While the prevailing rock in the upper part of the mountain is the porphyry, this always contains irregular, angular fragments of other rocks, so that it is difficult to obtain a hand specimen that does not show one or more of these inclosed fragments. In places the rock fragments are so abundant as to make up the larger part of the ledge, constituting a breccia with the porphyry as the cement. Such a breccia may be seen on the south slope of Kearsarge at the 2,000 foot level, and continues to appear up to the 2,150 foot level. The fragments constituting the breccia vary in size from a fraction of an inch up to two feet or more in diameter. Those most frequently seen are of phyllite.

There is a large mass of this phyllite in the southern slope of Mount Kearsarge, which is crossed by the mountain trail at the 1,425 foot level. From this trail the phyllite area may be traced easterly and southeasterly to the first brook on the mountain side. The phyllite constitutes a mass in the south side of the mountain about one-fourth mile in length and 100 feet thick.

The phyllite is of a dark gray or slate color, of slightly greasy feel, and is very thinly laminated. The surfaces of the laminæ show a fine, delicate crinkling which is seen on a cross-section to be due to the beginning of a new structure almost at right angles to the lamination. The new structure is produced partly by a very fine faulting and partly by the compression of minute folds. There are beds of finely grained, light gray quartzite in the phyllite. They show that the present structure is parallel to the original bedding of the clay. There also appear on the laminæ minute dark spots, longer than wide, and pointed in shape, which are the beginnings of crystals, probably, of andalusite.

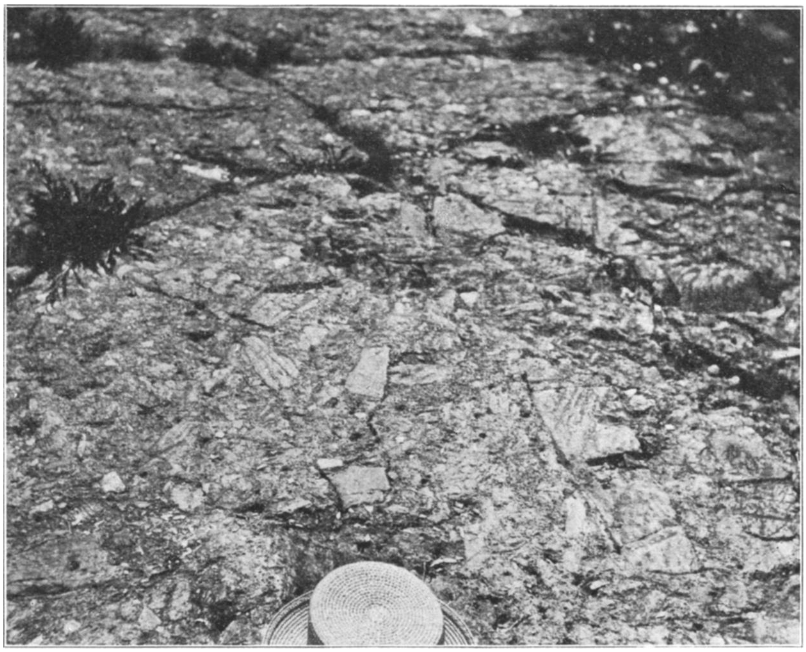

FIG. 2.— The breccia in Mt. Kearsarge — the surface of a ledge.

The phyllite mass has suffered extreme brecciation, being in large part a mass of simply indurated fragments. In part there is a peculiar regularity displayed in the brecciation. The breaking followed certain straight zones, only a few inches thick, within which the rock was shattered, and the fragments now occupy every conceivable position, while the rock between, several feet in thickness, is not broken, is not even folded. Why the rock yielded so completely through these zones with so little disturbance to the intervening rock is difficult to understand. Near the border of the large phyllite mass the fragments separated somewhat, and the unsolidified porphyry flowed in and crystallized, making the border into a porphyry-breccia. Some of this is well exposed at the side of the trail on the south slope, and is shown in the illustration.

In addition to the phyllite, there are, inclosed in the quartz-porphyry, fragments of gray quartzite, of glassy quartz, and of quartz-porphyry. The quartz-porphyry in fragments closely resembles, frequently, the quartz-porphyry inclosing them.

In Moat mountain the quartz-porphyry contains a smaller number of fragments. Among these are those of glassy quartz, of rusty mica-schist, of quartz-mica-schist, of quartz-porphyry, of quartzite, of biotite-gneiss, of muscovite-granite, and of a dark gray, rusty rock, probably a basic eruptive. In addition to these small fragments, there is a large mass of phyllite, identical with the Kearsarge phyllite and completely brecciated, making up a large part of the top of Moat. The fragments of this breccia vary in size from those that are very small up to those a foot across. Some of these fragments contain andalusite crystals.

CONCLUSIONS.

1. The Conway granite, the granite-porphyry, and the quartz-porphyries, including probably those found in fragments, were formed by the solidification of a single magma.

The sedimentary rocks of this area, together with the underlying crystallines, were profoundly and thoroughly shattered, presumably by a disturbance associated with the coming of this magma into its present position.

2. The shattered condition of the phyllite affords a means of estimating the greatest depth at which this magma could have solidified. Included, as the shattered phyllite was in the molten magma, the latter was not at a depth greater than that of the zone of fracture for the phyllite.

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